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# Determination of the recipe of a colorant mixture


## Abstract

The target colour to be rematched is established by the CIE colour type coordinates a* and b* and a depth of shade parameter. From the standard colours available the reflectance spectra of colour samples dyed in different depths are recorded and stored. From the reflectance spectra the calibration colour locations of the standard colours for the desired depth of shade are calculated. The appropriate depth of shade plane is segmented into non-overlapping triangular areas the corners of which are given by the calibration colour locations. Those triangular areas are sought in which the colour location of the target colour to be rematched lies. The relative proportions of the three standard colours belonging to the appropriate triangular area which are required for the rematching of the target colour are then calculated.

(Fig. 4)

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Determination of the recipe of a colorant mixture

The invention relates to a method and an apparatus for determining the recipe of a colorant mixture, according to the preambles of patent claim 1 and patent claim 12, respectively, and to the use of the method and of the apparatus in connection with a dyeing and/or printing process and with the preparation of a colorant mixture.

Any area of industry concerned with coloration has to rematch shades of colour to an original or to design new collections of colours and shapes. In recent years there has been a great deal of development in those areas of industry as a result of the linking together of design, colour computer graphics, colorimetry and computer stations which has become possible.

It is now possible to display a colour and shape original on a screen, for example by means of a scanner or a video camera, to vary it as desired as regards shaping and coloration, and to print out that design using a colour printer, for example an ink-jet printer, on any desired substrate. Rematching of the original still presents difficulties, however, since the required shades of colour have to be selected, for example from a comprehensive colour atlas; collections of up to 15 000 different shades are known, as are computer-aided systems that store a very large number of shades which they are able to make visible using a screen or to print out on any desired substrate using a colour printer. Colour atlases of the traditional type and those of the electronic type provide recipes for each class of colorant; those recipes may differ from substrate to substrate.

The production of such colour atlases requires a great deal of expenditure. The colour atlases are of course valid only for as long as the basic colorants, the methods of application and the substrates remain unchanged. Each alteration requires at least partial or even complete renewal of the colour atlases. This procedure is therefore extremely uneconomic.

Also known are colorimetric recipe-matchings by means of spectrophotometry. This form of recipe-matching also has shortcomings in terms of rematching since the known

programs are not sufficiently selective and generally produce a number of recipes, with the result that specialists are required to select the "correct" recipe from those suggested. Each of those selected recipes is used to produce a test colour which is then adjusted once or even several times, depending on the experience of the specialist.

All the known colorimetric systems for rematching an original that are established in practice today use reflection curves from the original, and attempt to approximate to the reflection curves of the original by mixing known colorants.

Because the reflection data depend on the colorants and it is generally not possible to use the colorants used in the original, the rematch will generally have a reflection curve that deviates from the original to a greater or lesser extent. In order to keep the deviation as small as possible, mixtures of different colorants are used to compensate for the differences in the reflection curves. This procedure is time-consuming and requires a great deal of experience with the colorants used.

With the method according to the invention for calculating the recipe of a colorant mixture and the corresponding apparatus according to the invention, the mentioned shortcomings of the known systems are eliminated.

The method according to the invention and the apparatus according to the invention are characterised by the features of patent claims 1 and 12, respectively. The dependent claims 2-6 relate to preferred developments.

The method of the invention is characterised in that each original can be rematched virtually as exactly as desired, since it is not the best approximation to the reflection curve of the original that is sought; rather the colour of the original is defined precisely in the colour space and precisely that colour location in the colour space is sought out for the recipe-matching.

The method of the invention is based on the known CIE L*a*b* colour coordinate system with the difference that the brightness axis L* is replaced by the depth of shade parameter FT. The advantage of this procedure is that colour locations of the same depth of shade or of the same colour strength lie in one plane of the colour space.

An example of a suitable depth of shade parameter FT is the standard depth concentration

which is indicated not only in the known 2/1, 1/1, 1/3, 1/6, 1/12 and 1/25 depths, but can be divided further, for example into steps of 1/10 of the standard depth concentration or smaller. Furthermore, there may be used as depth of shade parameters values from reflection measurements which are obtainable in accordance with the instructions in "Textilveredlung", 1986, pages 299 to 304. Further depth of shade parameters are described, for example, in W. Schultze, "Farbenlehre und Farbmessung", 3rd Edition, Springer-Verlag, pages 76-84, and in Schönpflug "Die Anwendung von Küpenfarbstoffen zum Färben von Polyamidfasern", Melliand, 38-2/1957, pages 173-177. The publications listed above and those cited hereinafter are intended merely for disclosure purposes as a reference for the person skilled in the art and are not material to the present invention.

An advantage of dividing up the colour space into planes of different depths of shade, all the shades of colour in a plane having the same depth of shade, is that once the depth of shade or the colour strength of the original to be rematched is established or determined, the appropriate depth of shade plane of the colorants to be used is known and the desired colour type, a* and b* data, can be obtained from a single colorant, from a mixture of two or from a mixture of three. The fact that the depth of shade plane is known means that the use concentration of each colorant is fixed for that depth of shade plane, so the ratio of mixtures of the colorants can be determined by relatively simple methods of calculation. Suitable methods of calculation are, for example, purely mathematical or geometric, especially computer-controlled, approximation methods.

The colour type coordinates a* and b* correspond to those of the known CIE L*a*b* colour coordinate system. In the above-mentioned FTa*b* colour space, colour locations of different depth of shade or colour strength lie in different planes one above another. When a depth of shade parameter from reflection measurements is used, an additional weighting of the data relating to the colour perception of the eye and/or to the perceived colour has proved advantageous.

The use according to the invention of the recipe determination method in a dyeing and/or printing process is described in patent claim 7. Patent claim 8 relates to the use according to the invention of the method for preparing a colorant mixture. Patent claim 9 relates to a dyeing and/or printing process according to the invention that incorporates the recipe determination method. Patent claims 13, 14 and 15 describe the dyeing apparatus according to the invention, the colorant mixing apparatus according to the invention and the printing apparatus according to the invention.

The invention is explained in detail below with reference to the drawings, in which:

| | |
|---|---|
| Fig. 1 shows | a depth of shade plane selected by way of example with segmentation into triangular areas drawn in, |
| Fig. 2 shows | a selected segment from Fig. 1, |
| Fig. 3 shows | the segment from Fig. 2 with the structuring drawn in, |
| Fig. 4 shows | the colour space according to the invention, defined by the coordinate axes FT, a* and b*, |
| Fig. 5 shows | a flow diagram of the recipe calculation method of the invention, |
| Fig. 6 shows | a block diagram of a recipe calculation apparatus according to the invention, |
| Fig. 7 shows | a block diagram of an apparatus according to the invention for preparing a colorant mixture and |
| Fig. 8 shows | a block diagram of a dyeing and/or printing apparatus according to the invention. |

The basis of the present invention is the colour space shown diagrammatically in Fig. 4, which is defined by the coordinate axes a*, b* and FT. The coordinate axes a* and b* correspond exactly to the chromatic or colour type coordinates a* and b* of the CIE L*,a*,b* colour space. In this case, however, instead of the luminance coordinate L* in the L*,a*,b* colour space, the third coordinate axis is the depth of shade FT; that may be, for example, the so-called standard depth concentration or another depth of shade parameter, such as that described, for example, in "Textilveredelung" 1986, pages 299-304. The depth of shade FT, which, independently of the colour type, defines locations of the same depth of shade, can be detected visually or calculated from reflectance spectra.

Each colour location P in the colour space is unambiguously defined by its three coordinates FT, a* and b*. Colour locations of the same depth of shade lie in a common depth of

shade plane FT = constant.

Fig. 1 shows such a depth of shade plane, for example 2/3 the standard depth concentration, having eight plotted colour locations P1-P8 each corresponding to a pure, i.e. an unmixed, standard colour (standard colorant, standard coloured ink): yellow (P1), golden yellow (P2), orange (P3), red (P4), red-blue (P5), blue (P6), turquoise (P7) and black (P8). The colour locations P1-P8, i.e. the colour type coordinates a* and b* of points P1-P8, are produced by a CIE colour measurement from test colours (physical colour samples) in the appropriate depth of shade, in this case, therefore, for example 2/3 of the standard depth concentration. The colour locations of the unmixed (pure) standard colours are referred to hereinafter as the calibration colour locations.

In order to colour a specific substrate in a given depth of shade, a characteristic colorant concentration is required for each standard colour. This, as well as the desired depth of shade, depends *inter alia* on the colorant itself, on the method of application and on the substrate. The connection between concentration and depth of shade for each commercially available standard colour is generally known (e.g. standard depth concentration table) or can be determined easily by means of test colours. For an understanding of the present invention it is important to appreciate that the depth of shade of a coloration using a mixture of standard colours does not change, irrespective of the mixing ratio, if the standard colours involved are used in the concentrations required for the depth of shade in question and weighted with the mixing ratio. If, for example, the concentrations $C_1$, $C_6$ and $C_7$ are required for the three colours P1, P6 and P7, respectively, for a specific depth of shade, any random mixture of those three standard colours having a mixing ratio $X_1$, $X_6$ and $X_7$ ($X_1+X_6+X_7=1$) will produce a coloration of the appropriate depth of shade if the colorant concentrations are set at $X_1 \cdot C_1$, $X_6 \cdot C_6$ and $X_7 \cdot C_7$. That empirical fact allows the problem of colour rematching, which is *per se* a three-dimensional problem, to be reduced to a two-dimensional problem since the depth of shade to be rematched is given and all further calculations take place only in the appropriate depth of shade plane.

As will be seen from the further description of the invention, the calibration colour locations, i.e. the a* and b* coordinates in the relevant depth of shade plane, i.e. the depth of shade of the colour to be rematched, of the standard colours available for the rematching must be known. The colour to be rematched will be referred to hereinafter as the target colour, its colour location as the target colour location and its colour coordinates as the target depth of shade coordinate and target colour type coordinates.

The calibration colour locations can be determined by various methods. One obvious method is to make test colours in variously finely graded depths of shade with each standard colour and to measure the associated colour type coordinates a* and b*. In accordance with a further aspect of the invention, however, it is advantageous to proceed as follows:

Test colours with different concentrations of colorant are made with each standard colour and the reflectance spectrum of each test colour is recorded and stored. There are calculated from the reflectance spectra, for each test colour, the CIE colour type coordinates a* and b* and the depth of shade, for example as described in "Textilveredelung" 1986, pages 299-304 or in W. Schultze "Farbenlehre und Farbmessung", pages 76-84, 3rd edition, Springer Verlag or in Schönpflug "Die Anwendung von Küpenfarbstoffen zum Färben von Polyamidfasern", Melliand-38-2/1957, pages 173-177. Alternatively, the depths of shade can be determined by visual assessment and/or the test colours can be made with given depth of shade gradations.

Those measurements produce, for each standard colour, the functional relationships between the depth of shade coordinate FT or the colour type coordinates a* and b* and the particular colorant concentrations c in tabular form (discrete individual points):

$$FT_i = f_i(c) \qquad a^*_i = g_i(c) \qquad b^*_i = h_i(c)$$

The index i denotes the individual standard colours and the functions f, g and h symbolise the functional relationships with the concentrations c.

To determine the calibration colour location of a standard colour i in a specific target depth of shade plane the concentration c required is determined from the relationship $FT_i = f_i(c)$ and used in the relationships $a^*_i = g_i(c)$ and $b^*_i = h_i(c)$ to give the coordinates a* and b* of the calibration colour location of the standard colour i at the given target depth of shade FT. (Intermediate values are interpolated between the discrete individual points.)

According to the invention, therefore, the calibration colour locations of the standard colours are not calculated in advance or stored for every possible depth of shade plane, but are calculated from the reflectance spectra of the test colours or from the relationships

determined therefrom between the concentrations and the colour space coordinates FT, a* and b* for the particular depth of shade plane in question. Only the reflectance spectra or the said relationships are therefore given or stored for each standard colour.

There is generally understood by the calculation of the recipe of a colorant mixture or the rematching of a colour the task of determining the proportions of the individual colours in a set of given standard colours (colorants, coloured inks) of defined characteristics that, when mixed, produce on a substrate the same perceived colour (within a given tolerance range) as a given colour sample, i.e. the target colour to be rematched with a specific target colour location. In the present case, therefore, a coloration of the substrate with the colorant mixture to be determined must coincide in terms of depth of shade and colour type (a*, b*) with the target colour to be rematched.

First of all the target colour coordinates $FT_S$, $a_S$* and $b_S$* of the target colour to be rematched are determined. The target colour type coordinates $a_S$* and $b_S$* are calculated in the conventional manner according to CIE from the reflectance spectrum of the colour sample to be rematched. The target depth of shade $FT_S$ is either determined visually or, likewise, as already mentioned, calculated from the reflectance spectrum, for example by filtration (weighted integration over the wavelength range). The target colour coordinates may of course also be available directly, for example from earlier measurements or the like. In Fig. 1 the colour location of an example of a target colour is shown by the point $P_S$, it being assumed that the depth of shade plane shown is the target depth of shade $FT_S$ of the target colour.

The aim of the subsequent steps of the method or calculation is to determine the relative proportions $X_i$ of the individual standard colours in the colorant mixture that is being sought, which is to produce on the substrate the target colour location $P_S$ with the target depth of shade $FT_S$. All the calculations take place only in the depth of shade plane given by the target depth of shade $FT_S$.

As is clear from Fig. 1, (in the example shown) eight standard colours having the calibration colour locations P1-P8 are available. This produces a very large number of different possible mixtures. According to one of the most important aspects of the invention, however, only mixtures of a maximum of three standard colours are permitted for the rematching of a target colour. For that purpose, the depth of shade plane of the colour space given by the target depth of shade $FT_S$ is segmented into triangular areas, the

corners of which are the calibration colour locations of the standard colours intended for the rematching and the boundary lines of which, which are generally curved, are in each case the colour locations of all mixtures of two standard colours. The triangular areas are so selected that they do not overlap, with the result that every point inside a triangular area represents the colour location of a three-colour mixture of the relevant standard colours determined by the corners of the triangular area. Each colour location of a triangular area is thus defined by a single recipe, that is to say by a single mixture of the three relevant standard colours which comprises only a single standard colour if the colour location in question coincides with one of the three corners of the triangular area, or two standard colours if the colour location lies on a boundary line of the triangular area, or all three standard colours if the colour location is inside the triangular area. In the selected example in Fig. 1, these are the three colours P2, P3 and P8.

The segmenting of the depth of shade planes into triangular areas can be carried out with a great variety of standard colours, the only proviso being that the colour space (i.e. the area of the depth of shade plane for all depths of shade) is as well covered as possible. The standard colours *per se* that are used for the rematching and thus enter into the segmenting can be selected according to a very wide range of criteria, for example the application characteristics of the colorants used, the level of fastness, the price, availability, stock catalogue, etc.. The same applies also to the segmenting, i.e. to the establishment of the triangular areas themselves. In this way it is possible to include all those criteria in the calculation of the recipe. In addition, it is possible in this manner also to calculate different recipes, for example a recipe based on, for example, highly light-fast colorants and a recipe based on, for example, especially economical colorants, and so on.

In order to calculate the recipe it is therefore necessary first of all to ascertain to which of the triangular areas divided in accordance with the above the target colour location $P_S$ of the target colour to be rematched belongs; this establishes which standard colours (maximum of three) are involved in the mixture that is sought. Then the relative proportions (totalling 100 %) of the relevant standard colours have to be determined. The steps required for this are described in detail below.

First the boundary lines of the individual triangular areas must be calculated. This is done by means of point by point calculation of the colour locations a*, b* of all the mixtures (in gradations as fine as desired) of two standard colours, for example in accordance with the theory of Kubelka and Munk.

According to Kubelka-Munk, for each colorant located on a substrate there can be found for each wavelength a characteristic quotient $K/S$ according to the following equation:

$$K/S = (1-R)^2/2R$$

In that equation, K is a constant determined by the light absorption, S is a constant determined by the light scatter and R is the reflectance measured at the relevant wavelength. K is determined mainly by the colorant, S mainly by the substrate.

For a mixture of n colorants in the relative proportions

$$X_1 \cdots X_n \left( \text{where } \sum_{i=1}^{n} X_i = 1 \right),$$

$$X_1 \cdot \left( \frac{K}{S}(1) - \frac{K}{S}(S) \right) + X_2 \left( \frac{K}{S}(2) - \frac{K}{S}(S) \right) + \cdots X_n \left( \frac{K}{S}(n) - \frac{K}{S}(S) \right) + \frac{K}{S}(S) = \frac{K}{S}(M)$$

In that equation $\frac{K}{S}(1) \cdots \frac{K}{S}(n)$ represent the quotients $K/S$ for each individual colorant, calculated from the reflectances of the individual colorants $1 \cdots n$ on the substrate, $\frac{K}{S}(S)$ represents the quotient $K/S$ for the substrate alone, calculated from the reflectances of the pure substrate S, and $\frac{K}{S}(M)$ represents the resultant quotient $K/S$ for the mixture of all the colorants on the substrate.

The reflectance spectra for the standard colours involved on the substrate in question are known in accordance with the above explanations (for example stored in a computer), as is the reflectance spectrum for the substrate. Using the above formula, therefore, the mixture quotient $\frac{K}{S}(M)$ for any desired mixture (proportions $X_1 \cdots X_n$) of the standard colours can be calculated for all wavelengths.

From the mixture quotient $\frac{K}{S}(M)$, the reflectance spectrum $R_M(\lambda)$ of the colour mixture

can be found using the formula:

$$R_M = \left(1 + \frac{K}{S}(M)\right) - \sqrt{\left(\left[1 + \frac{K}{S}(M)\right]^2 - 1\right)}$$

wherein $R_M$ is the reflectance at one wavelength and has to be calculated for all wavelengths.

There can then be calculated from the reflectance spectrum $R_M(\lambda)$ of the colour mixture, analogously to the calculation of the calibration colour location of the standard colours described hereinbefore, the colour locations of the individual colour mixtures, especially also those colour locations that define the above-mentioned boundary lines of the individual triangular areas. For each colour location thus calculated, the associated mixing ratio defined by the relative proportions $X_1$ - $X_n$ of the standard colours involved is thus known. (Fig. 2).

By means of a simple comparison of coordinates, it is then possible to determine the triangular area to which the target colour location $P_S$ to be rematched belongs and which colours the (maximum of) three standard colours involved in the mixture are.

Further calculation to determine the sought mixing ratio of the target colour location $P_S$ can be restricted to the triangular area found.

As a first step the triangular area can then be structured, for example as shown in Fig. 3, using grid lines. These grid lines are calculated in the same way as the boundary lines of the triangular areas, the only difference being that they define the colour locations of mixtures of three (instead of mixtures of two) of the standard colours involved. Fig. 3 shows grid lines for relative proportions of 8, 20, 40, 60, 80 and 96 % of standard colour P1 (~ horizontal) and relative proportions of 25, 50 and 75 % of standard colour P6 (~ vertical). The colour location designated $P_x$, for example, defines a mixture of 20 % of standard colour P1, 80 % x 25 % = 20 % of standard colour P6 and 80 % x 75 % = 60 % of standard colour P7.

If the target colour location to be rematched, as in Fig. 3 for example the target colour location $P_{S1}$ marked by a circle, should happen to lie on a boundary line or at the inter-

section of two grid lines, the mixing ratio that is sought can be read off immediately. Otherwise the number of grid lines can be increased (finer gradations), it being possible for this to be restricted to the area in which the target colour location lies, for example the target colour location $P_{S2}$ marked by a cross in Fig. 3. This process can be continued with increasing accuracy (resolution) until the target colour location does lie at an intersection and the mixing ratio has thus been found. Alternatively, interpolation methods known *per se* can be used.

An alternative method for determining the mixing ratio required for the target colour location consists in the application of more modern iterative optimisation algorithms, such as the simplex algorithm described, for example, in "Analytical Chemistry", Vol. 45, No. 3, March 1973. Such algorithms generally lead to reduced expenditure on programming and calculation, but do not alter the fundamental steps of the method of the invention in any way.

In Fig. 5 the individual steps of the method of the invention that are described above are summarised in the form of a flow diagram.

In the method of the invention, a very wide variety of classes of colorants can be used to rematch a colour original and it is of no consequence whether water-soluble or disperse colorants are used; there are used especially disperse, acid, metal complex, reactive, vat, sulfur and direct dyes and pigments, as well as cationic dyes. Natural dyes, developing dyes, for example naphthol dyes, and food dyes also come into consideration. Any mixtures of the mentioned dyes are also suitable.

As an example of the different classes of colorant, reference is made to the Colour Index: Colour Index, Third Edition, 1970/1971: Acid Dyes, Volume 1, pages 1001 to 1562; Basic Dyes, Volume 1, pages 1607 to 1688; Direct Dyes, Volume 2, pages 2005 to 2478; Disperse Dyes, Volume 2, pages 2479 to 2743; Food Dyes, Volume 2, pages 2773 to 2788; Leather Dyes, Volume 2, pages 2799 to 2835; Natural Dyes, Volume 3, pages 3225 to 3256; Pigments, Volume 3, pages 3267 to 3390; Reactive Dyes, Volume 3, pages 3391 to 3560; Solvent Dyes, Volume 3, pages 3563 to 3648; Vat Dyes, Volume 3, pages 3719 to 3844.

The method according to the invention is suitable for rematching a colour on any substrate, especially on textile fibre materials, such as silk, leather, wool, polyamide

fibres, polyurethane fibres, cellulose-containing fibre materials, such as cotton, linen and hemp, as well as cellulose viscose and cellulose, polyester fibres, polyacrylic fibres, paper, foils and metals, for example polymer-coated aluminium. Also suitable are mixtures of the mentioned fibre materials, for example mixtures of cotton with polyester fibres or with polyamide fibres.

In the method of the invention, it is necessary to specify the substrate that is to be used for the rematching, since the colorant concentrations depend *inter alia* on the substrate. The substrate is included in the calculation when recording the reflectance spectra of the test colours with different colorant concentrations.

The method of the invention and the application of that method, as well as a sampling apparatus that works with the method of the invention, offer the advantage that, for example, if one colourant in a colorant manufacturer's range is altered it is no longer necessary to produce an entire new colour atlas, but merely to store the reflectance spectrum of the new colorant. From that spectrum the combinations of two shades and the mixtures of the new colorant with two other colorants can be calculated as described.

A further advantage of the method of the invention is that all the data required for rematching, for example the reflectance spectra of the colorants, can be stored in a computer or on a diskette, with the result that without producing a single test coloration, merely by means of reading in different diskettes or inputting calibration data, a large number of "colour atlases" are available.

Virtually all commercially available colorants can be used as colorants in the method according to the invention.

The Examples that follow serve to illustrate the invention. In those Examples, parts and percentages are by weight.

<u>Example 1:</u> In the rematching of a shade of colour that follows, it is assumed that the reflectance spectra of the colorants to be used for the rematching are available, that the colour space has been segmented by the calibration colour locations of various colorants, and that the segmentation corresponds to the segmentation indicated in Fig. 1.

The shade of colour to be rematched is a shade of blue having the following characteristic

data: a* = -18.15; b* = -27.18; FT = 0.66 (2/3 standard depth concentration).

The above-mentioned data define the target colour location in the FTa*b* colour space. The shade of colour to be rematched lies in the segment that is characterised by the colorants having the coordinates P1, P6 and P7 (see Fig. 3, ⊙ symbol). In order to determine the shade of colour to be rematched from the mixing ratio of the colorants of that segment, the segment is structured by calculating the a* and b* data of combinations of two shades (mixture of the colorants having the coordinates: P1 and P6, P1 and P7, P6 and P7) as described.

The following Tables show the a* and b* data of some two-colorant combinations. The colorant mixture relates in each case to the depth of shade parameter FT = 0.66. In the following Tables, FSP1 = colorant having the calibration colour location P1, FSP6 = colorant having the calibration colour location P6 and FSP7 = colorant having the calibration colour location P7 in the FTa*b* colour space.

Table 1:

| Colorant mixture | a* | b* |
|---|---|---|
| 100 % FSP1 + 0 % FSP7 | - 3.45 | 93.87 |
| 96 % FSP1 + 4 % FSP7 | -40.47 | 63.82 |
| 80 % FSP1 + 20 % FSP7 | -56.89 | 37.22 |
| 60 % FSP1 + 40 % FSP7 | -59.21 | 21.48 |
| 40 % FSP1 + 60 % FSP7 | -56.49 | 8.76 |
| 20 % FSP1 + 80 % FSP7 | -49.87 | - 4.68 |
| 8 % FSP1 + 92 % FSP7 | -41.68 | -16.02 |
| 0 % FSP1 + 100 % FSP7 | -32.55 | -26.70 |

Table 2:

| Colorant mixture | a* | b* |
|---|---|---|
| 100 % FSP6 + 0 % FSP7 | 12.22 | -46.16 |
| 75 % FSP6 + 25 % FSP7 | 2.24 | -42.79 |
| 50 % FSP6 + 50 % FSP7 | -7.44 | -38.54 |
| 25 % FSP6 + 75 % FSP7 | -17.53 | -33.88 |
| 0 % FSP6 + 100 % FSP7 | -32.55 | -26.70 |

Table 3:

| Colorant mixture | | | a* | b* |
|---|---|---|---|---|
| 100 % FSP1 | + | 0 % FSP6 | - 3.45 | 93.87 |
| 96 % FSP1 | + | 4 % FSP6 | -23.36 | 55.59 |
| 80 % FSP1 | + | 20 % FSP6 | -28.91 | 23.00 |
| 60 % FSP1 | + | 40 % FSP6 | -26.43 | 5.32 |
| 40 % FSP1 | + | 60 % FSP6 | -20.68 | -7.19 |
| 20 % FSP1 | + | 80 % FSP6 | -10.97 | - 21.17 |
| 8 % FSP1 | + | 92 % FSP6 | -0.69 | -33.01 |
| 0 % FSP1 | + | 100 % FSP6 | 12.22 | -46.16 |

By combining the calculated a* and b* data, the above-mentioned structuring leads to Fig. 3, all points totalling 100 %; for example the first five points on the line with 96 % FSP1 are composed as follows: 96 % FSP1 + 0 % FSP6 + 4 % FSP7; 96 % FSP1 + 1 % FSP6 + 3 % FSP7; 96 % FSP1 + 2 % FSP6 + 2 % FSP7; 96 % FSP1 + 3 % FSP6 + 1 % FSP7; 96 % FSP1 + 4 % FSP6 + 0 % FSP7.

The characterisation of the depth of shade parameter, for example as 2/3 standard depth concentration, means that the use concentration (e.g. g of colorant per kg of printing paste) of those colorants in this depth of shade required for a specific substrate is known:

colorant having the coordinates P1 in FT = 0.66: 16.9 g/kg
colorant having the coordinates P6 in FT = 0.66: 45.4 g/kg
colorant having the coordinates P7 in FT = 0.66: 48.1 g/kg

The shade of blue desired by way of example, having the data: FT = 0.66; a* = -18.15; b* = -27.18 is in the depth of shade plane where FT = 0.66, on a structuring intersection at 8 % FSP1 and 46 % FSP6 and 46 % FSP7. The sum of the mixture must be 100 % ( $\triangleq$ 1 ).

In order to determine the amounts to be used, it is necessary to know the amount of colorant for different depths of shade. The amount of the colorant having the coordinates P1 to be used for different depths of shade FT is:

colorant having the coordinates P1 in: FT = 1.0 : 36.4 g/kg
FT = 0.66 : 16.9 g/kg
FT = 0.33 : 8.4 g/kg

FT = 0.16 : 4.1 g/kg

The amount of the colorant having the coordinates P6 to be used for different depths of shade FT is:

| | |
|---|---|
| colorant having the coordinates P6 in: | FT = 1.0 : 71.3 g/kg |
| | FT = 0.66 : 45.4 g/kg |
| | FT = 0.33 : 22.1 g/kg |
| | FT = 0.16 : 10.5 g/kg |

The amount of the colorant having the coordinates P7 to be used for different depths of shade FT is:

| | |
|---|---|
| colorant having the coordinates P7 in: | FT = 1.0 : 79.0 g/kg |
| | FT = 0.66 : 48.1 g/kg |
| | FT = 0.33 : 20.9 g/kg |
| | FT = 0.16 : 9.5 g/kg |

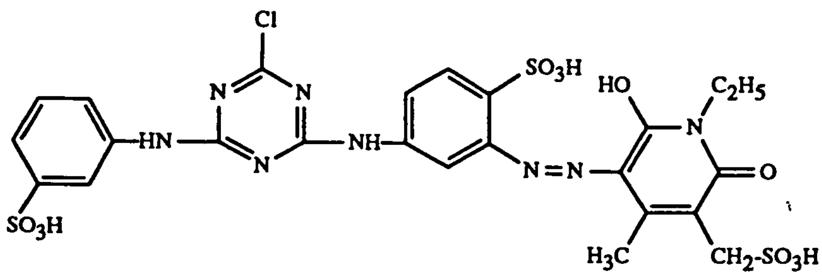
From the above amounts of the colorants having the coordinates P1, P6 and P7 to be used the substrate-specific concentration curve can be determined. For the desired shade of colour having the data FT = 0.66; a* = -18.15; b* = -27.18 the following amounts to be used in g of colorant per kg of printing paste are found:

| | |
|---|---|
| 1.35 | g/kg of colorant having the coordinates P1 |
| 20.9 | g/kg of colorant having the coordinates P6 |
| 22.14 | g/kg of colorant having the coordinates P7 |

Using the mixture indicated, a cotton fabric can be printed in the desired shade of blue in standard depth concentration 2/3.

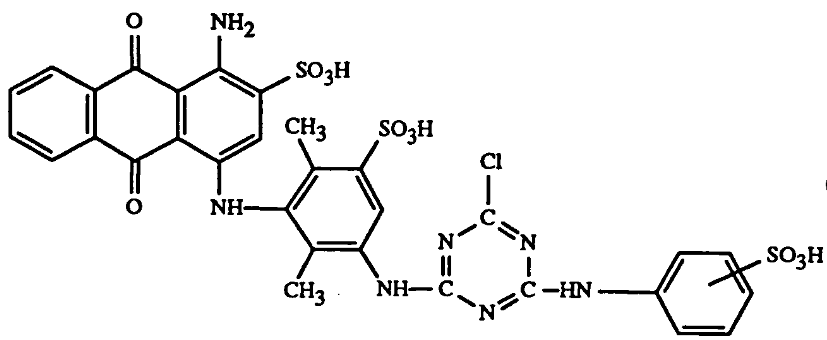
The colorants used are reactive dyes having the following constitutions:

FSP1:



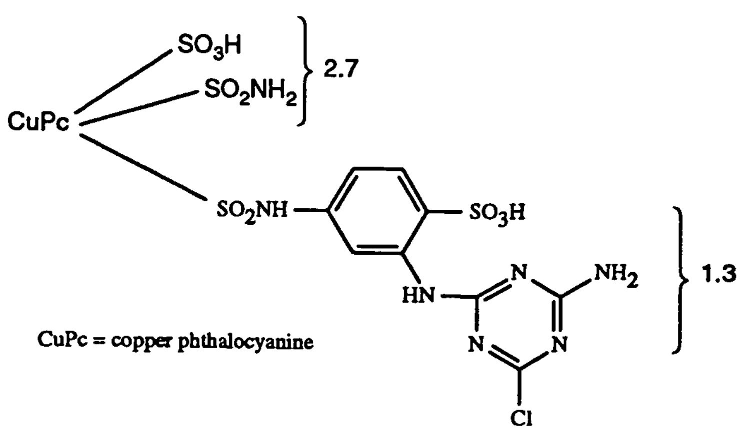
(100)

FSP6:



(101)

FSP7:



(102)

CuPc = copper phthalocyanine

Example 2: A colour location (green shade) having the coordinates FT = 0.66; a* = -46.00; b* = 16.00 is selected for the rematching. In the rematching that follows, it is assumed that the reflectance spectra of the colorants to be used for the rematching are available, that the colour space has been segmented using the calibration colour locations of various colorants, that the segmentation corresponds to the segmentation indicated in Fig. 1 and that this segment has been calculated and structured in accordance with Example 1, see Figs 2 and 3. The colour location having the desired coordinates lies neither on a structuring intersection nor on one of the lines connecting the coordinates P1P7, P1P6, P6P7. In order to calculate this colour location, the above description of the

method is followed. The coordinates in standard depth concentration 2/3 selected for the rematching are shown in Fig. 3 by a + sign. The calculation according to the invention gives 63 parts of the yellow colorant having the coordinates P1. For the associated proportions in the mixture of the colorants having the coordinates P6 and P7 the following distribution of those colorants is calculated: 26.5 % of the colorant having the coordinates P6 and 73.5 % of the colorant having the coordinates P7. The proportion of yellow is 63 parts, so the remaining 37 parts in the mentioned % ratio of the colorants having the coordinates P6 and P7 are as follows:
9.8 parts of the blue colorant having the coordinates P6
27.2 parts of the turquoise colorant having the coordinates P7.

To calculate the concentration of the colorants in the printing paste, the following concentration is calculated in accordance with the instructions in Example 1 for the depth of shade parameter FT = 0.66 (2/3 standard depth concentration):

| | |
|---|---|
| 10.6 | g/kg of the colorant having the coordinates P1 |
| 4.4 | g/kg of the colorant having the coordinates P6 |
| 13.1 | g/kg of the colorant having the coordinates P7. |

Using the mixture indicated, a cotton fabric is printed in the desired green shade in the standard depth concentration 2/3.

The method according to the invention is preferably carried out using a suitably programmed computer. An embodiment of a recipe calculating apparatus according to the invention is shown diagrammatically in Fig. 6.

The apparatus comprises a commercially available personal computer 100, for example of the 386 type, with an input keyboard 101 and a display screen 102, as well as a memory 103. Also connected to the computer 100 is a reflectance spectrometer 104. In the memory 103 are stored the reflectance spectra of test colours, in different depths of shade, of the standard colours available. These can be recorded, for example, using the spectrometer 104. The spectrometer 104 is also used to record the reflectance spectrum of a colour sample 105 to be rematched. The spectrometer may also be designed to calculate from the reflectance spectrum the colour type coordinates a* and b* and the depth of shade FT of the colour sample 105. Otherwise, these parameters are calculated in the computer 100. Using the keyboard 101, the target colour coordinates of the target colour to be rematched can also be input directly. Using the standard colour data stored in the

memory 103 and the data of the colour sample to be rematched that has been input or read in from the spectrometer 104, the computer carries out the above-described calculation steps according to the invention and produces the result on the display screen 102.

Alternatively, or in addition, the computer 100 can be provided with a further input 106 by way of which target colour location coordinates of a colour to be rematched or to be produced can be supplied to the computer from a different input apparatus. That input apparatus may be, for example, a computer-aided design apparatus (CAD) by means of which an image or a design recorded, for example, by means of a scanner or a video camera or produced by some other method is made visible on a screen and can be altered, especially as regards its colour, and which supplies the colour coordinates of the image to be produced to the computer.

Fig. 6 shows in a block diagram an embodiment of an apparatus according to the invention for producing a colorant mixture, for example a printing ink. The apparatus comprises a computer 100 having an input keyboard 101, a memory 103 and a reflectance spectrometer 104, as well as a mixing control means 200 that actuates a number of valves 201-206. The latter are in lines 211-216 which lead from supply tanks 221-226, one for each standard colour, to a mixing vessel 230.

The computer 100 calculates the proportions (recipe) of the standard colours required for rematching the colour sample 105 and passes these on to the mixing control means 200. On the basis of that data, the mixing control means actuates the valves 201-206 and allows the amounts of standard colours corresponding to the recipe to flow into the mixing vessel 230. Recipe-controlled mixing control means for preparing colorant mixtures are known *per se* and therefore do not require further explanation.

The apparatus for preparing a colorant mixture can also be used within a dyeing process or as part of a dyeing apparatus. In that case the colorant mixture to be used for the dyeing corresponding to the colour sample is prepared as described and then supplied to the dyeing process. In the preparation of the colorant mixture, the (known) basic concentrations of the individual standard colours required for the depth of shade to be achieved are weighted in accordance with the relative proportions found in the recipe determination of the standard colours specified therein and the standard colours are mixed accordingly.

The recipe calculation method according to the invention can be used especially also to

control a printing apparatus, especially an ink-jet printer. Fig. 8 shows, in a block diagram, an embodiment of a multi-colour ink-jet printer according to the invention, the conventional components not essential to an understanding of the invention having been omitted.

The printer comprises a first computer 100 with a memory 103 and a control input 106, a mixing control means 300, a number of, for example eight, metering devices 301-308, a corresponding number of supply vessels 321-328 for standard printing colours, eight colour printing heads 331-338 that are connected to the supply vessels by way of lines 311-318 containing the metering devices, and a second computer 400 having a control input 406 and a memory 403.

The second computer 400 serves to control the diverse conventional functions of the printer, including, for example, the positioning of the printing heads 331-338. It receives the commands for those functions from an external control apparatus, usually a computer or possibly also a CAD device, by way of its control input 406.

The first computer 100 receives, likewise from an external control apparatus by way of its control input, the information relating to the colour of the image points to be printed in the form of target colour coordinates FT, a* and b*. From that information and from the stored data of the standard colours in the supply vessels 321-328, it then calculates the recipe of the colour mixture to be printed and passes it to the mixing control means 300. The latter converts the recipe data into volumetric data with which it controls the metering devices 301-308. The latter supply an amount of the individual standard printing colours corresponding to the volumetric data to the associated printing heads in the form of individual droplets, and the printing heads apply them to the substrate.

The first computer thus calculates the recipes of the required colorant mixtures on the basis of given target colour coordinates. If a limited number of the colour locations to be printed with the printer are given, then each colour location, or the set of colour coordinates that defines it, can be characterised by a code, for example a number, and the codes can be stored in the memory 403, together with the recipes calculated for the colour locations that they characterise, in the form of a table. In order to print a desired colour it is then sufficient to supply the code associated with that colour to the second computer 400 by way of its input 406. On the basis of the code, the computer 400 then reads the requisite recipe from the memory 403 and transmits it to the mixing control means 300 for

further processing. This procedure is symbolised in Fig. 8 by the dotted line 401.

The first computer 100 and its memory 103 are in this case required only to set up the code-recipe table stored in the memory 403 and can be arranged outside the printer if the second computer 400 is programmed in such a manner that the code-recipe table can be loaded into the memory 403 from outside (Down Loading/Firmware).

The invention is, of course, not only suitable for ink-jet printers, but can be used advantageously anywhere that a colour original is to be translated exactly into a coloration system.

What is claimed is:

1. A method for determining the recipe of a colorant mixture that produces the same perceived colour on a substrate as a target colour to be rematched, the proportions of the individual colours in a set of given standard colours in the colorant mixture being determined, wherein in a three-dimensional cartesian colour space the three coordinate axes of which represent the two CIE colour type coordinates and a depth of shade coordinate

- using a target depth of shade coordinate and two target colour type coordinates a target colour location for the target colour to be rematched is established,

- in a target depth of shade plane of the colour space defined by the target depth of shade coordinate of the target colour location the calibration colour locations of the individual given standard colours expressed by the colour type coordinates are determined,

- the target depth of shade plane is segmented into non-overlapping triangular areas the corners of which are the calibration colour locations of in each case three of the standard colours the boundary lines of which represent the colour locations of all mixtures of two of the three standard colours establishing a triangular area and the interior points of which indicate the colour locations of all three-colour mixtures of the relevant three standard colours for this target depth of shade,

- those standard colours are determined that establish the triangular area in which the target colour location of the target colour to be rematched is to be found,

- that mixture of the three standard colours so determined is found, the colour location of which coincides within a given tolerance range with the target colour location of the target colour to be rematched,

- and the relative proportions of the three standard colours in the mixture thus found are output and/or stored, as the result of the recipe determination.

2. A method according to claim 1 wherein the calibration colour locations of the standard colours are calculated from their reflectance spectra.

3. A method according to claim 1 wherein the calibration colour locations of the standard

colours are determined by means of the colorimetric measurement of physical colour samples having the target depth of shade defined by the target colour location of the target colour to be rematched.

4. A method according to claim 1 wherein the target colour location of the target colour to be rematched is established by means of colorimetric measurement of the target colour.

5. A method according to claim 1 wherein in order to determine the desired mixture of the three standard colours, the associated colour location is calculated for a selected mixture and compared with the target colour location in order for the relative proportions of the standard colours in the selected mixture to be varied successively until the calculated colour location coincides within the given tolerance range with the target colour location of the target colour to be rematched.

6. A method according to claim 1 wherein the segmentation of the target depth of shade plane into triangular areas proceeds in accordance with given selection criteria, such as application characteristics and/or price bands.

7. The use of the method according to claim 1 in a dyeing and/or printing process, wherein the basic concentration of the individual standard colours required to obtain the target depth of shade established by the target colour location of the target colour to be obtained is weighted in accordance with the relative proportions, found in the recipe determination, of the standard colours specified therein.

8. The use of the method according to claim 1 for the preparation of a colorant mixture.

9. A dyeing and/or printing process wherein a substrate is coloured in a desired target colour in a given target depth of shade, wherein a colorant mixture the recipe of which is determined in accordance with the method according to claim 1 is applied to the substrate.

10. A dyeing and/or printing process according to claim 9 wherein the basic concentrations of the individual standard colours required to obtain the given target depth of shade are weighted in accordance with the relative proportions, found in the recipe determination, of the standard colours specified therein.

11. The use of the method according to claim 1 to control a multi-colour printing

apparatus, especially a multi-colour ink-jet printer, that is equipped with a given set of standard colorants, the proportions of the standard colorants to be applied to a substrate that are required to obtain a desired target colour being controlled on the basis of the recipe determination.

12. An apparatus for determining the recipe of a colorant mixture that produces the same perceived colour on a substrate as a target colour to be rematched, having a computer (100) that determines from stored data of a set of given standard colours and from input colorimetric data of the target colour the proportions of the individual standard colours in the colorant mixture to be calculated, wherein the computer (100) calculates the recipe on the basis of a three-dimensional cartesian colour space the three coordinate axes of which represent the two CIE colour type coordinates and a depth of colour coordinate, the target colour to be rematched being established by a target depth of shade coordinate and two target colour type coordinates, and wherein the computer (100)

- determines, in a target depth of shade plane of the colour space defined by the target depth of shade coordinate of the target colour location, the calibration colour locations, expressed by the colour type coordinates, of the individual given standard colours,

- segments the target depth of shade plane into non-overlapping triangular areas the corners of which are the calibration colour locations of in each case three of the standard colours, the boundary lines of which are the colour locations of all mixtures of two of the three standard colours that establish a triangular area, and the interior points of which indicate the colour locations of all three-colour mixtures of the relevant three standard colours,

- determines those standard colours that establish the triangular area in which the target colour location of the target colour to be rematched is to be found,

- finds that mixture of the three standard colours so determined the colour location of which coincides within a given tolerance range with the target colour location of the target colour to be rematched,

- and indicates and/or stores, as the result of the recipe determination, the relative proportions of the three standard colours in the mixture thus found.

13. A dyeing apparatus wherein there is an apparatus for determining the recipe of a colorant mixture according to claim 12.

14. An apparatus for preparing a colorant mixture, having an apparatus (100-105) for determining the recipe of the colorant mixture to be prepared and having a mixing and metering apparatus (200-230), controlled by that apparatus (100-105), for standard colours kept in reserve, wherein the apparatus for determining the recipe is constructed in accordance with claim 12.

15. A multi-colour printing apparatus having a number of supply vessels (321-328) for standard printing colours, having a number of printing heads (331-338) associated with the supply vessels and connected by way of metering devices (301-308) and having a control device (400, 300) for the metering devices and the printing heads, wherein there is a recipe calculating apparatus (100) that, on the basis of colour data supplied to it and stored data relating to the standard printing colours, controls the proportions of the standard printing colours to be applied by the printing heads.

16. A printing apparatus according to claim 15 wherein the recipe calculating apparatus (100) is constructed in accordance with claim 12.

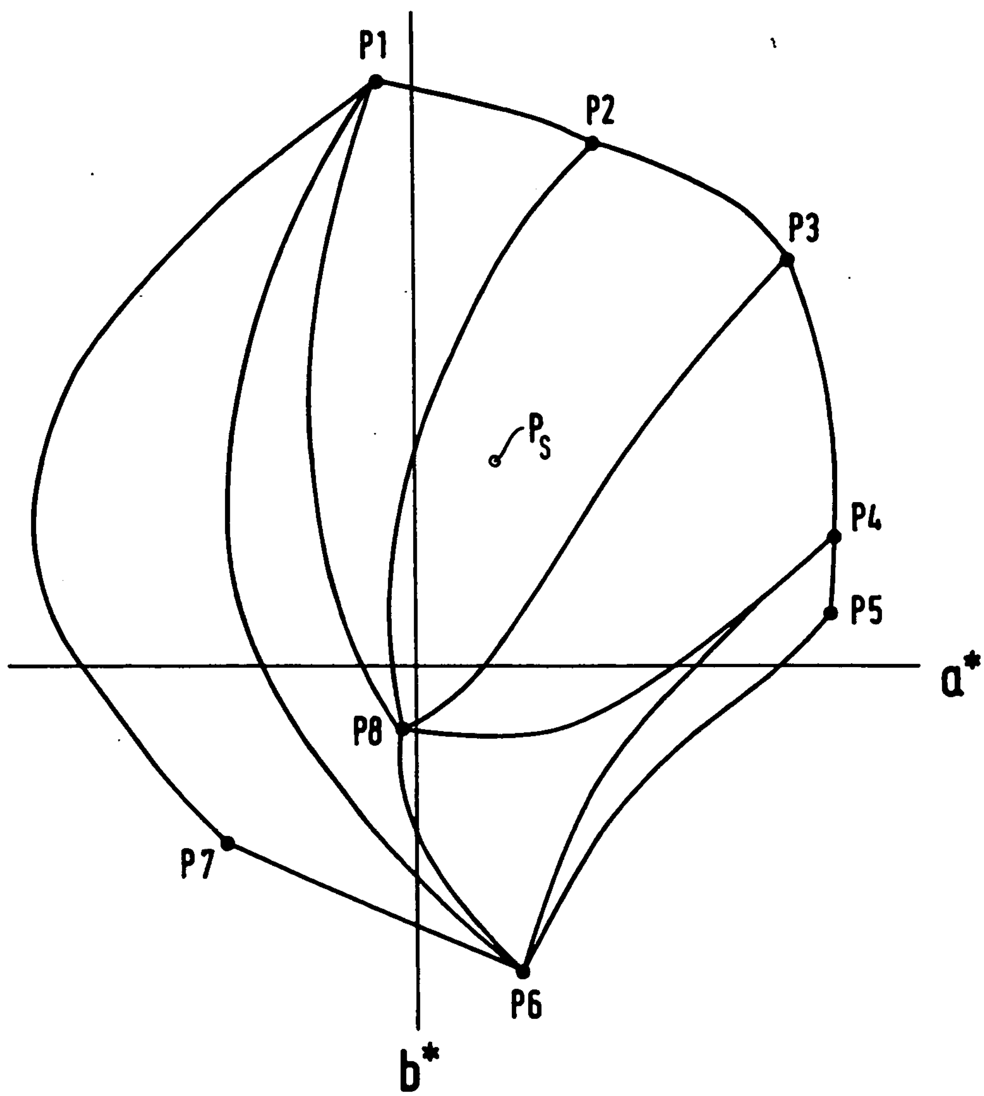
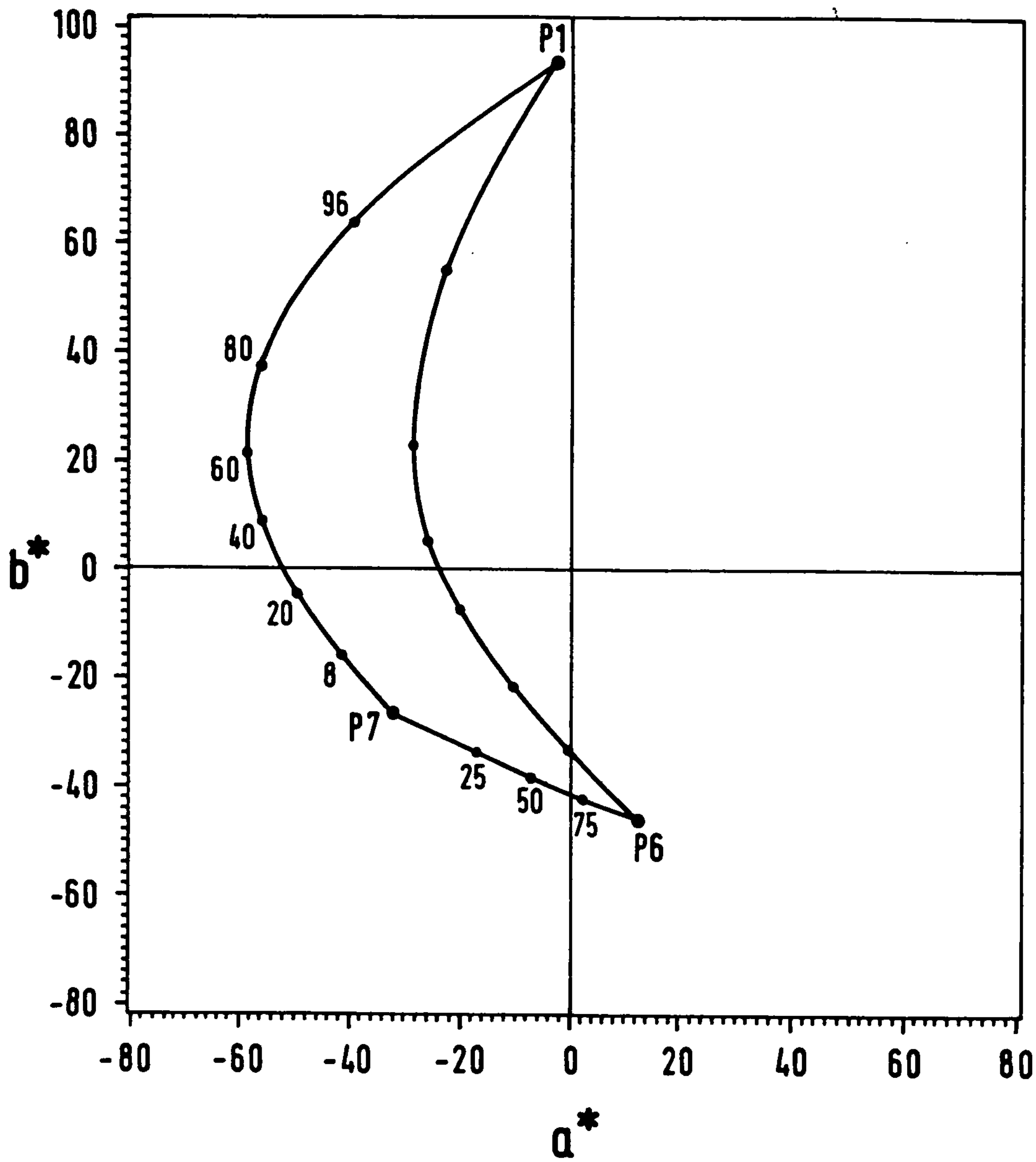



Fig. 1



100
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60
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20
0
-20
-40
-60
-80
b*
-80
-60
-40
-20
0
20
40
60
80
a*
P1
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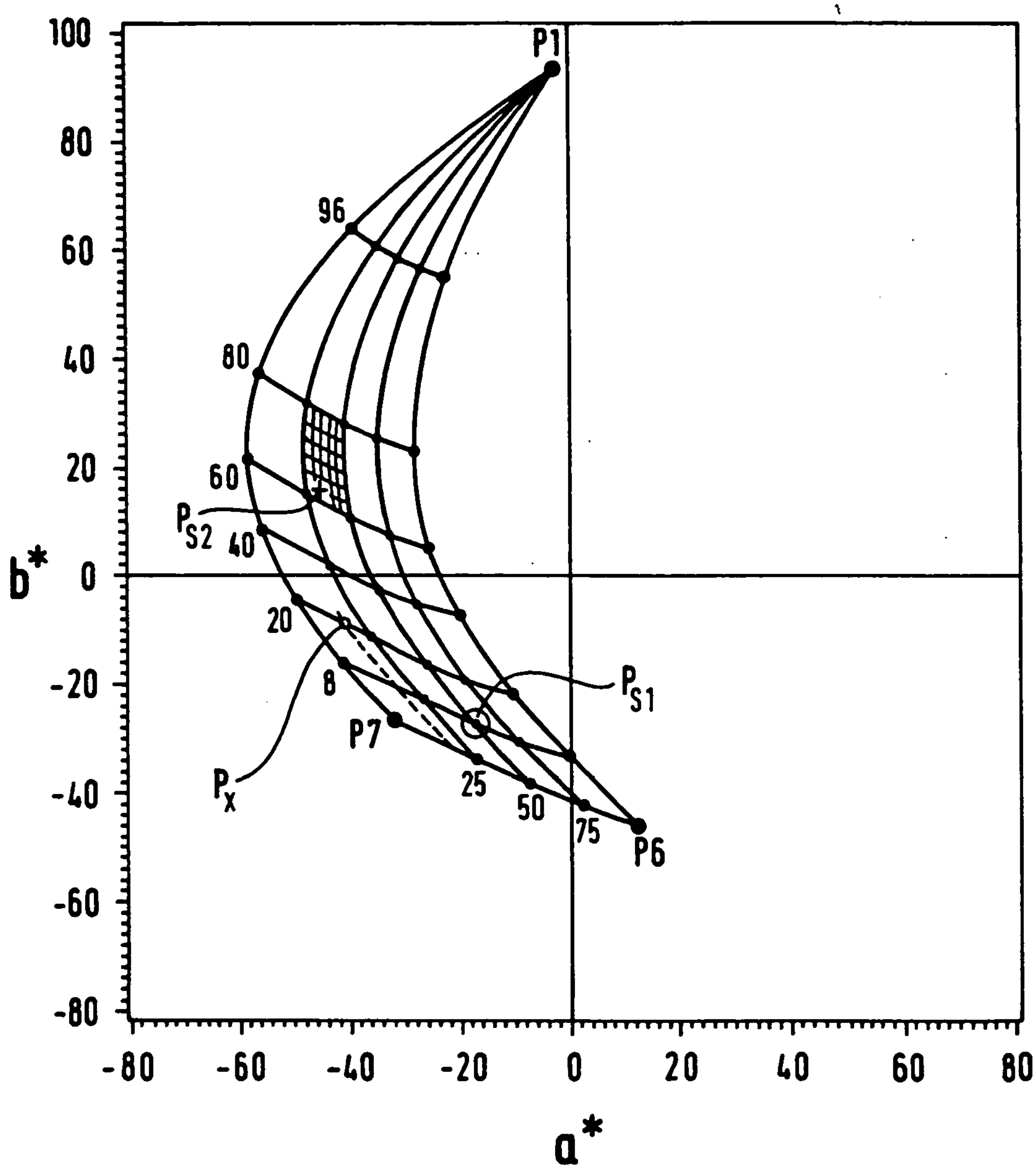
60
40
20
8
P7
25
50
75
P6


Fig. 2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P7
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75
P6
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$P_{S1}$
$P_X$
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-80
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-40
-20
0
20
40
60
80
b*
a*

Fig. 3

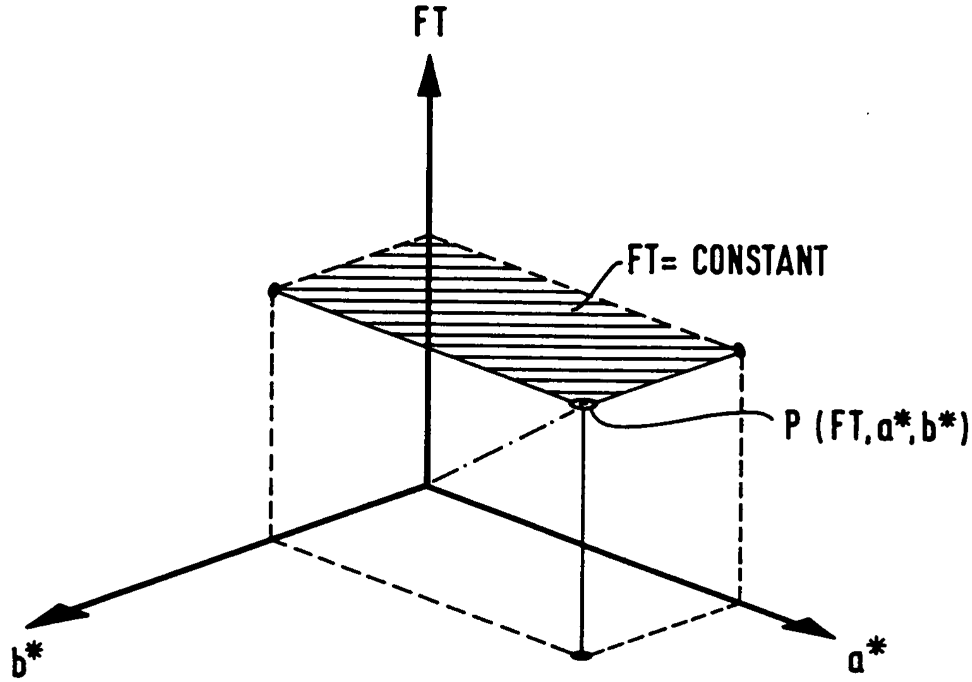



Fig. 4

THE REFLECTANCE SPECTRA OF THE STANDARD COLOURS OF COLOUR SAMPLES IN A VARIETY OF DEPTHS OF SHADE ARE RECORDED.

↓

THE TARGET COLOUR TYPE COORDINATES AND THE TARGET DEPTH OF SHADE OF THE TARGET COLOUR TO BE REMATCHED ARE GIVEN OR DETERMINED.

↓

THE STANDARD COLOURS FOR THE SEGMENTATION AND CALCULATION OF THE CALIBRATION COLOUR LOCATIONS IN THE TARGET DEPTH OF SHADE ARE SELECTED.

↓

THE TARGET DEPTH OF SHADE PLANE IS SEGMENTED INTO NON-OVERLAPPING TRIANGULAR AREAS USING THE SELECTED STANDARD COLOURS.

↓

THE BOUNDARY LINES OF THE TRIANGULAR AREAS ARE CALCULATED AND THE TRIANGULAR AREA IN WHICH THE TARGET COLOUR LOCATION LIES IS FOUND.

↓

THE RELATIVE PROPORTIONS ARE DETERMINED OF THE STANDARD COLOURS THAT DEFINE THE TRIANGULAR AREA FOUND.

↓

THE RECIPE IS OUTPUT.

Fig. 5

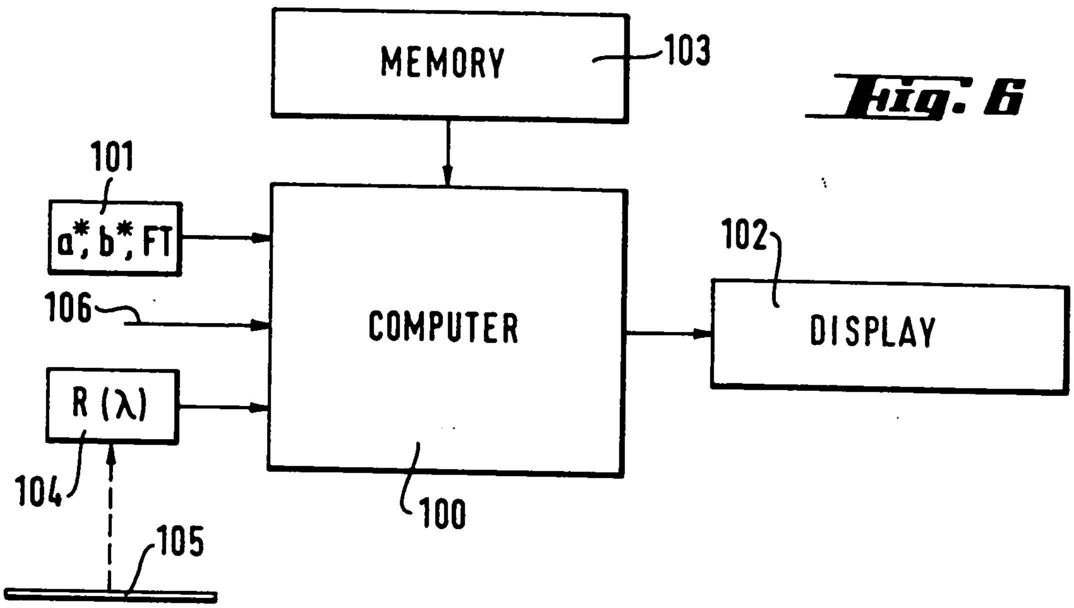
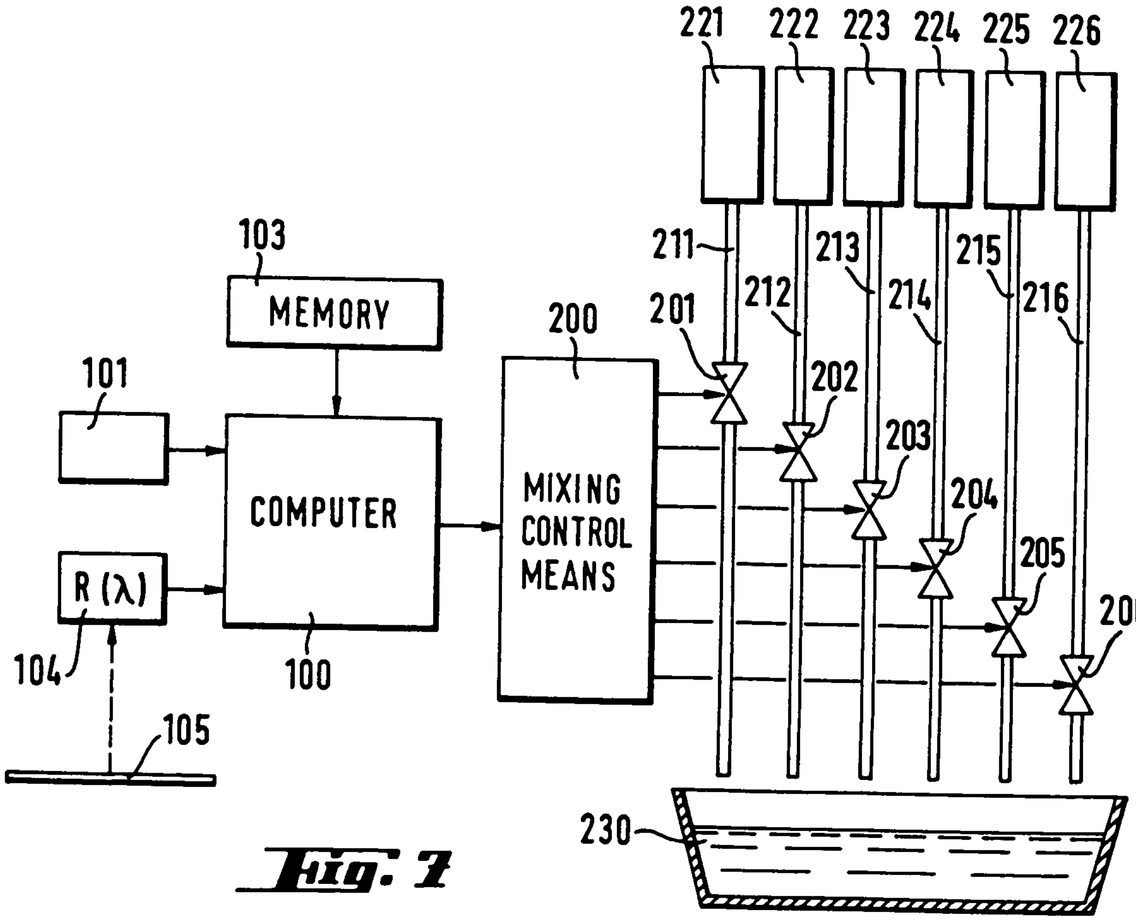

MEMORY
103
101
a*, b*, FT
106
COMPUTER
102
DISPLAY
R (λ)
104
100
105

Fig. 6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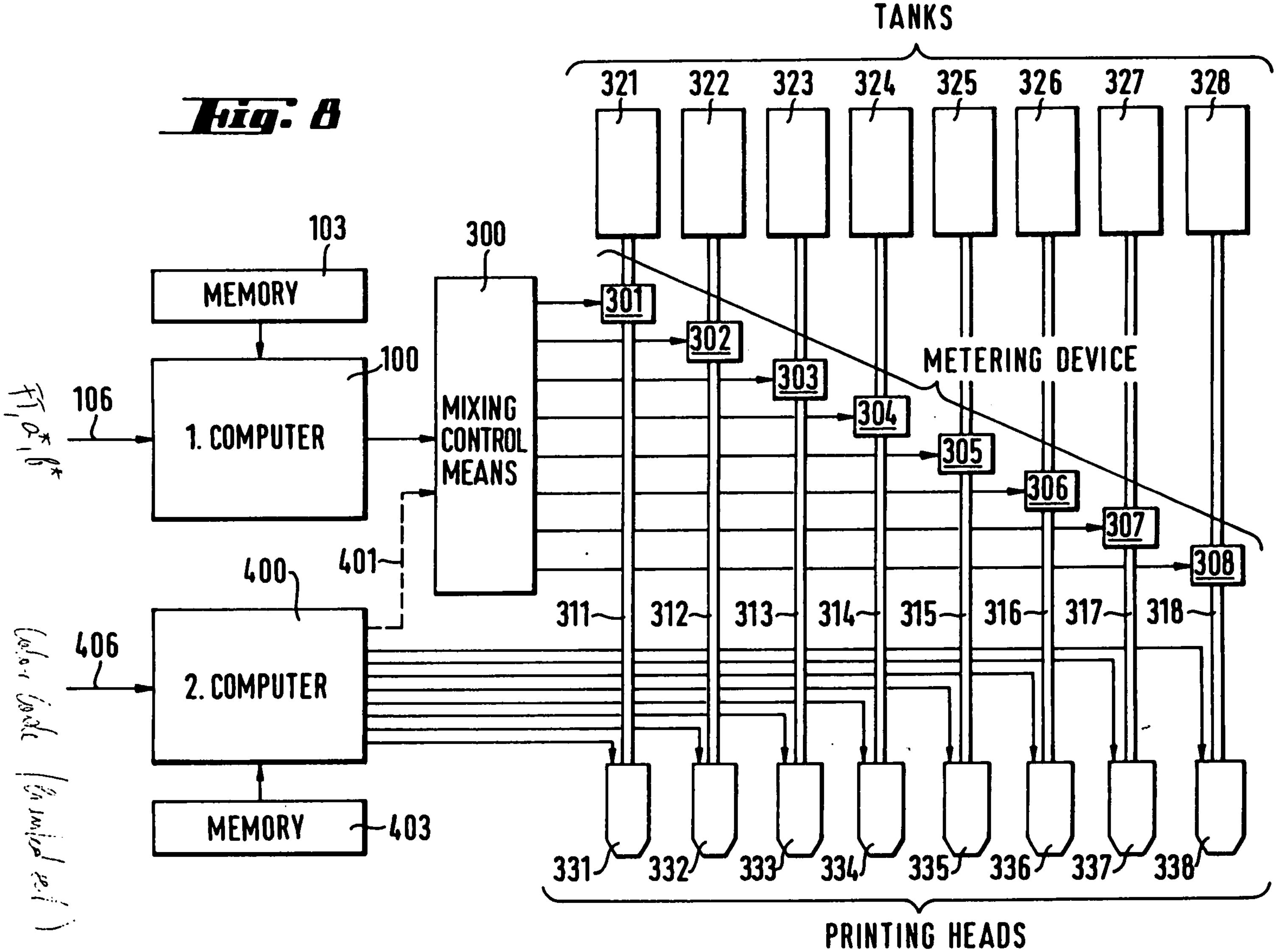
226
211
213
215
212
214
216
201
200
103
MEMORY
202
101
203
COMPUTER
MIXING
CONTROL
MEANS
204
R (λ)
205
206
104
100
105
230

Fig. 7

Fig. 8


TANKS
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325
326
327
328
MEMORY
103
1. COMPUTER
100
106
FT, a*, b*
MIXING CONTROL MEANS
300
301
302
303
304
305
306
307
308
METERING DEVICE
401
400
2. COMPUTER
406
Color Code (Ca ...)
311
312
313
314
315
316
317
318
MEMORY
403
331
332
333
334
335
336
337
338
PRINTING HEADS

ABRÉGÉ
ZUSAMMENFASSUNG
ABSTRACT